

APPENDIX A

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
a	Thermal diffusivity	ft ² /day or ft ² /hr
a'	Shortest dimension	ft
A	Sinusoidal temperature amplitude	°F
A _d	Duct cross-sectional area	ft ²
c	Specific heat	Btu/lb °F
c _p	Specific heat of air at constant pressure	Btu/lb °F
C	Volumetric heat capacity	Btu/ft ³ °F
C _f	Volumetric heat capacity in frozen condition	Btu/ft ³ °F
C _u	Volumetric heat capacity in unfrozen condition	Btu/ft ³ °F
d	Thickness of soil layer	ft
D _e	Equivalent duct diameter	ft
e	Roughness factor	ft
erf	Error function: $\text{erf } z = (2/\sqrt{\pi}) \int_0^z e^{-\mu^2} d\mu$, where $\text{erf } \infty = 1$ and $\text{erf } (-z) = -\text{erf } z$	dimensionless
exp(x)	e ^x	dimensionless
f	Frequency of sine wave	cycles/day
F	Air freezing index	degree-days
f'	Friction factor	dimensionless
h	Heat transfer coefficient	Btu/ft ² hr °F
h _{rc}	Surface conductance for combined radiation and convection	Btu/ft ² hr °F
h _d	Draft head	inches of water
h _f	Friction head	inches of water
h _v	Velocity head	inches of water
H	Stack height	ft
I	Air thawing index	degree-days
I _f	Floor thawing index	degree-days
k	Coefficient of thermal conductivity	Btu/ft ² hr °F per in.
K	Thermal conductivity	Btu/ft hr °F
K _f	Thermal conductivity in frozen condition	Btu/ft hr °F
K _u	Thermal conductivity in unfrozen condition	Btu/ft hr °F
L	Volumetric latent heat of fusion	Btu/ft ³
m	Duct spacing	ft
ln	Natural logarithm	dimensionless
ℓ	Duct length	ft

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
l_b	Allowance for bends, etc., in duct	ft
l_e	Equivalent duct length	ft
l_s	Length of straight duct	ft
MAT	Mean Annual temperature	°F
n	"n"-factor = $\frac{\text{surface index}}{\text{air index}}$	dimensionless
nF	Surface freezing index	degree-days
nI	Surface thawing index	degree-days
N_R	Reynolds number	dimensionless
P	Period of sine wave	365 days
Q	Latent heat per linear foot of slurry backfill	Btu/ft
r	Radius	ft
R	Thermal resistance	ft ² hr °F/Btu
S	Pile spacing	ft
s	Length of pipeline	ft
t	Time	hours or days
T	Temperature	°F
T_o	Initial temperature	°F
T_R	Temperature rise in duct air	°F
T_s	Surface temperature	°F
T_S	Soil temperature	°F
T_w	Water temperature	°F
V	Velocity of flow	ft/s
V_o	Initial temperature of the soil with respect to 32°F	°F
v_s	Average surface temperature with respect to 32°F	°F
w	Water content	percent dry weight
X	Depth of freeze or thaw	ft
α	Thermal ratio = v_o/v_s	dimensionless
γ_d	Dry unit weight	lb/ft ³
ϵ	Efficiency	percent
λ	Lambda coefficient	dimensionless
μ	Fusion parameter	dimensionless
ν	Kinematic viscosity	ft ² /hr
π	Pi	3.14
ρ	Density of air	lb/ft ³
ϕ	Heat flow to duct	Btu/ft ² per hr